When does a central bank's balance sheet require fiscal support?

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Yet another balance sheet simulation?

- Hall and Reis (2013), Carpenter et al. (2013), Greenlaw et al. (2013) examine likely scenarios, based on historically normal behavior of interest rates and demand for central bank liabilities.

- We study these scenarios, but also look for unlikely, scenarios in which failure of fiscal-monetary coordination or excessive size of the central bank balance sheet could create a conflict between maintaining stable inflation and maintaining central bank solvency.

- We think that recent history teaches that considering unlikely, but disastrous behavior of asset markets, so as to be prepared if they occur and to reduce their likelihood, is worthwhile.

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- We think that recent history teaches that considering unlikely, but disastrous behavior of asset markets, so as to be prepared if they occur and to reduce their likelihood, is worthwhile.
- We look at complete, though simplified, economic model in order to study why a central bank's balance sheet matters at all and the consequences of a lack of fiscal backing for the central bank.

Contribution

- Interest rates, inflation, and seigniorage are endogenous, hence we can answer questions such as:

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  2. How does the sensitivity of the CB balance sheet to shocks (changes in real rate, inflation expectations,..) depend on interest rate policy? And is therefore conventional policy constrained by "solvency" issues?
  3. How does the size of the central bank balance sheet affect the potential for its needing direct fiscal support?

The model

- Simple, perfect-foresight, non-linear model.
  - Exogenous real interest rate ρ and income Y
  - Flexible prices

Households

- Households maximize

$$\int_0^\infty e^\beta \log C_t \, dt$$

subject to

$$C_t(1+\psi(v_t)) + \dot{F}_t + \frac{\dot{V}_t + \dot{M}_t + q_t \dot{B}^P}{P_t} = Y + \rho_t F_t + r_t \frac{V_t}{P_t} + (\chi + \delta - q_t \delta)\frac{B^P}{P} - \tau_t.$$

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- V: overnight reserves. B: Woodford (2001)-style bond (depreciates at rates δ, coupon $\delta + \chi$, duration δ^{-1})

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- V: overnight reserves. B: Woodford (2001)-style bond (depreciates at rates δ, coupon $\delta + \chi$, duration δ^{-1})
- The model used in simulations has population growth n and productivity growth γ.

Transactions technology

$$v_t = \frac{P_t C_t}{M_t}$$

$$\psi(v) = \frac{\psi_0 v}{1 + \psi_1 v}$$

- $\psi_1 < 0 \Rightarrow v_t^{-1}$ asymptotes to ψ_1^{-1} as $r_t \to \infty$
- $\psi_1 > 0 \Rightarrow$ Implies real balances go to zero when nominal rate reaches ψ_0/ψ_1^2.

Fiscal policy

- Financial Authority budget constraint:

$$g_t + (\chi + \delta - \delta q_t)\frac{B}{P} = \tau_t + \tau_t^C + q_t \frac{\dot{B}}{P_t}$$

- τ_t^C remittances from CB. $B = B^P + B^C$.

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- τ_t^C remittances from CB. $B = B^P + B^C$.
- Passive fiscal policy (except for possibly switching to active under explosive paths):

$$\tau_t = \xi_0 + \xi_1 q \frac{B}{P}$$

Conventional and unconventional monetary policy

- Reaction function for Interest on reserves:

$$\dot{r} = \theta_r \cdot \left(\bar{r} + \theta_\pi (\frac{\dot{P}}{P} - \bar{\pi}) - r \right)$$

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- Unconventional monetary policy: path for B^C (Treasuries held by CB)

Central bank budget constraint and rule for remittances

- The central bank budget constraint is:

$$q_t \frac{\dot{B}^C}{P_t} - \frac{\dot{V}_t + \dot{M}_t}{P_t} = (\chi + \delta - \delta q_t)\frac{B^C}{P} - r_t \frac{V_t}{P_t} - \tau_t^C$$

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- Rule for remittances:

$$\tau_t^C = max\left\{0, \chi \frac{B_t^C}{P_t} - r_t \frac{V_t}{P_t} - \bar{r}\mathcal{K}\right\} .$$

This approximates the the idea that the Fed holds bonds to maturity and does not mark to market, while using a rule that tries to keep bank capital $\mathcal{K} = qB^C/P - V$ constant.

A present value take on CB solvency and remittances

$$\underbrace{q\frac{B_0^C}{P_0} - \frac{V_0}{P_0}}_{\text{Mkt value of assts - reserves}} + \underbrace{\int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt}_{\text{PDV seigniorage}}$$

$$= \underbrace{\int_0^\infty \tau_t^C e^{-\int_0^t \rho_s ds} dt}_{\text{PDV remittances}}$$

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- PDV of remittances <u>does not depend</u> on:
  1. Future path of B^C (whether B^C is held to maturity or not)
  2. Accounting rules, e.g., rule for remittances, deferred assets ...
- Time path of τ^C *may* (but does not have to...)

Four levels of CB balance sheet problems

Level 1 Accounting capital (book value of $B^C - V - M$) < 0. Or rule for remittances implies $\tau^C = 0$ for some period.

- No fiscal support ($\tau^C < 0$) required. In fact, PDV of τ^C may actually increase.

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Level 2 $qB^C - V < 0$

- No fiscal support required as long as PDV seignorage $\int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt > V - qB^C$
- Depends on q (future path of r, premia) but also on size of V (whether households trade M for V)
- The higher duration δ^{-1}, the more likely this situation is to arise.
- The likelihood likely depends on conventional monetary policy.

Level 3 $qB^C - V + \int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt < 0$

- If inflation gets out of control, r becomes very high, $\frac{M}{P}$ may $\downarrow \rightarrow \int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt \downarrow$
- Fiscal support required ($\int_0^\infty \tau_t^C e^{-\int_0^t \rho_s ds} dt \rightarrow \tau_t^C < 0$ for some t). Fiscal policy may continue to be passive

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- These paths cannot be ruled out by a monetary authority with no fiscal powers.

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- Why not FTPL on CB budget constraint?
  Seignorage is a kind of tax, but its base disappears as the value of cash shrinks, so it cannot provide the real anchor required by a FTPL argument.

Solving the model

- Marginal utility

$$c^{-1} = \lambda \left(1 + \psi(v) + v\psi'(v)\right)$$

- Euler eq.

$$\beta - \rho = \frac{\dot{\lambda}}{\lambda}$$

- Fisher eq.

$$r - \frac{\dot{P}}{P} = \rho$$

- Money demand

$$v^2 \psi'(v) = r$$

- No arbitrage (long term bonds)

$$\frac{\chi+\delta}{q} - \delta + \frac{\dot{q}}{q} = r$$

$\rightarrow q_0 = (\chi+\delta)\int_0^\infty e^{-\left(\int_0^t r_s ds + \delta t\right)} dt$

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- Fisher + Taylor rule:

$$r_t = \int_0^\infty e^{-(\theta_\pi - 1)\theta_r s}\theta_r\theta_\pi(\rho_{t+s} + x_{t+s})\, ds + \frac{\bar{r} - \theta_\pi\bar{\pi}}{\theta_\pi - 1} + \kappa e^{(\theta_\pi - 1)\theta_r t}\, ds$$

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- Resource constraint:

$$C_0\left(\int_0^\infty (1+\psi(v))e^{-\int_0^t(\rho_s - \frac{\dot{C}}{C})ds} dt\right) = F_0 + (Y-g)\int_0^\infty e^{-\int_0^t \rho_s ds} dt$$

Results from a simple steady-state change

$\theta_\pi = 2.00$, $\rho = 0.01$, $\bar{\rho} = 0.01$, $\beta = 0.01$, $\psi_0 = 0.01$, $\psi_1 = 0.10$, $\theta_r = 0.60$, $F_0 = 2.00$, $V_0 = 3.00$, $B_0^C = 4.00$.

Table: Effect of 3% inflation scare

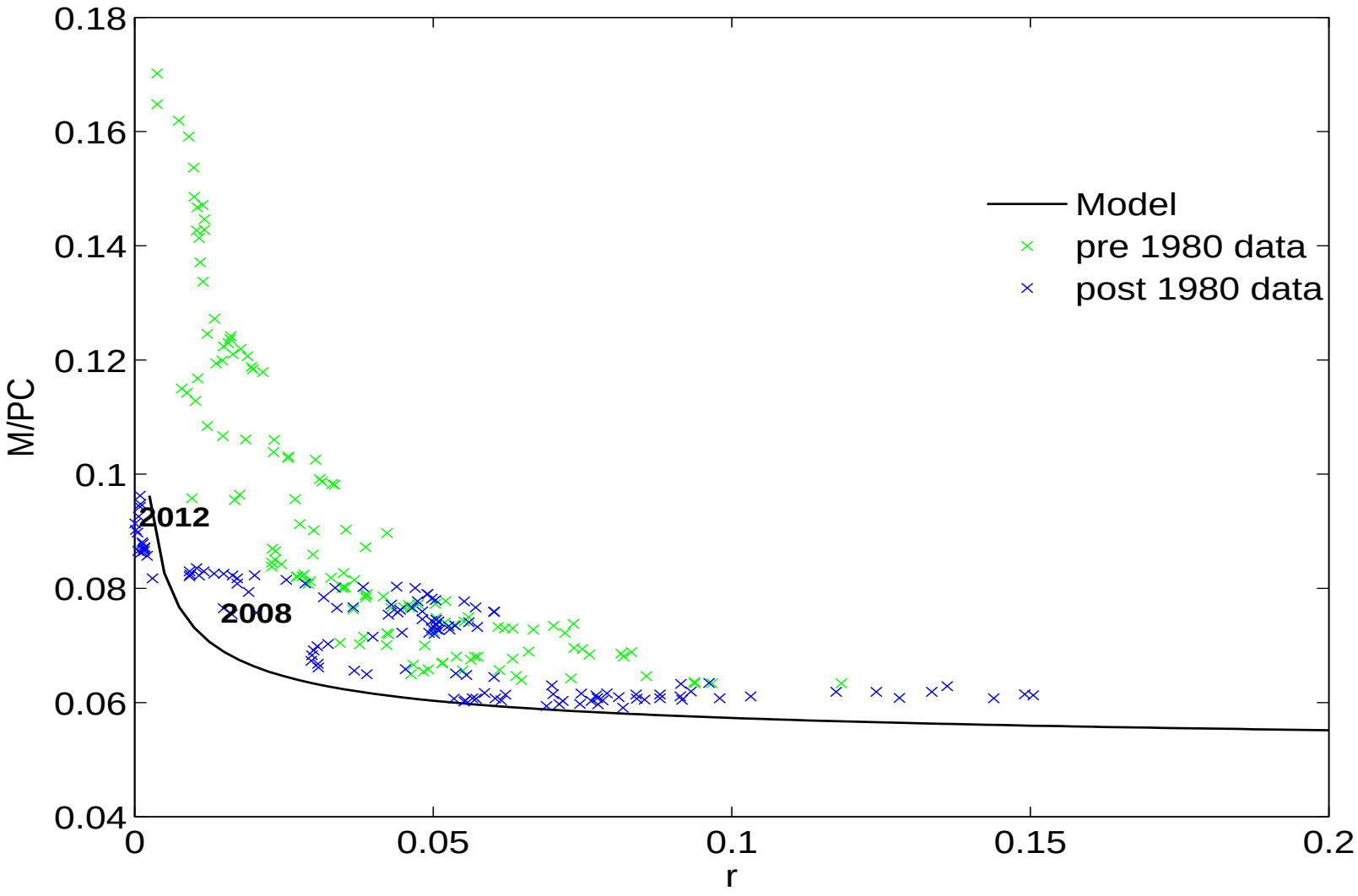
	base	after shock
r	.01	0.07
v	1.11	3.60
c_0	1.01	0.99
$m0$	.909	0.276
dp		0.0500
dm		-1.1911
dM		-1.1411
$dpvs$	0	3.0000

Duration	2.5	5	10	20
Direct proportional capital loss from r change				
	-0.15	-0.29	-0.5455	-1.0000
Funding gap to be filled with $dpvs$				
	0.5983	1.7823	3.4190	5.2602

Parameters

normalization, foreign assets					
$Y - g$	=	1	$F0$	=	0
initial assets, reserves, and currency (t=0 is Dec 31, 2012)					
B^C/P	=	.237	V/P	=	.132
M/P	=	.108			
discount rate, reversion to st.st., population and productivity growth					
β	=	0.01	γ	=	0.0075
φ_1	=	0.750	n	=	0.0075
monetary policy					
θ_π	=	2	θ_r	=	1
$\bar{\pi}$	=	0.02			
money demand					
ψ_0	=	0.00001	ψ_1	=	-0.05
(match M/P at $r = .0025$, ψ_{ss}=0.00056)					
bonds: duration and coupon					
δ^{-1}	=	6	χ	=	0.035

A scatter plot of short term interest rates and M/PC



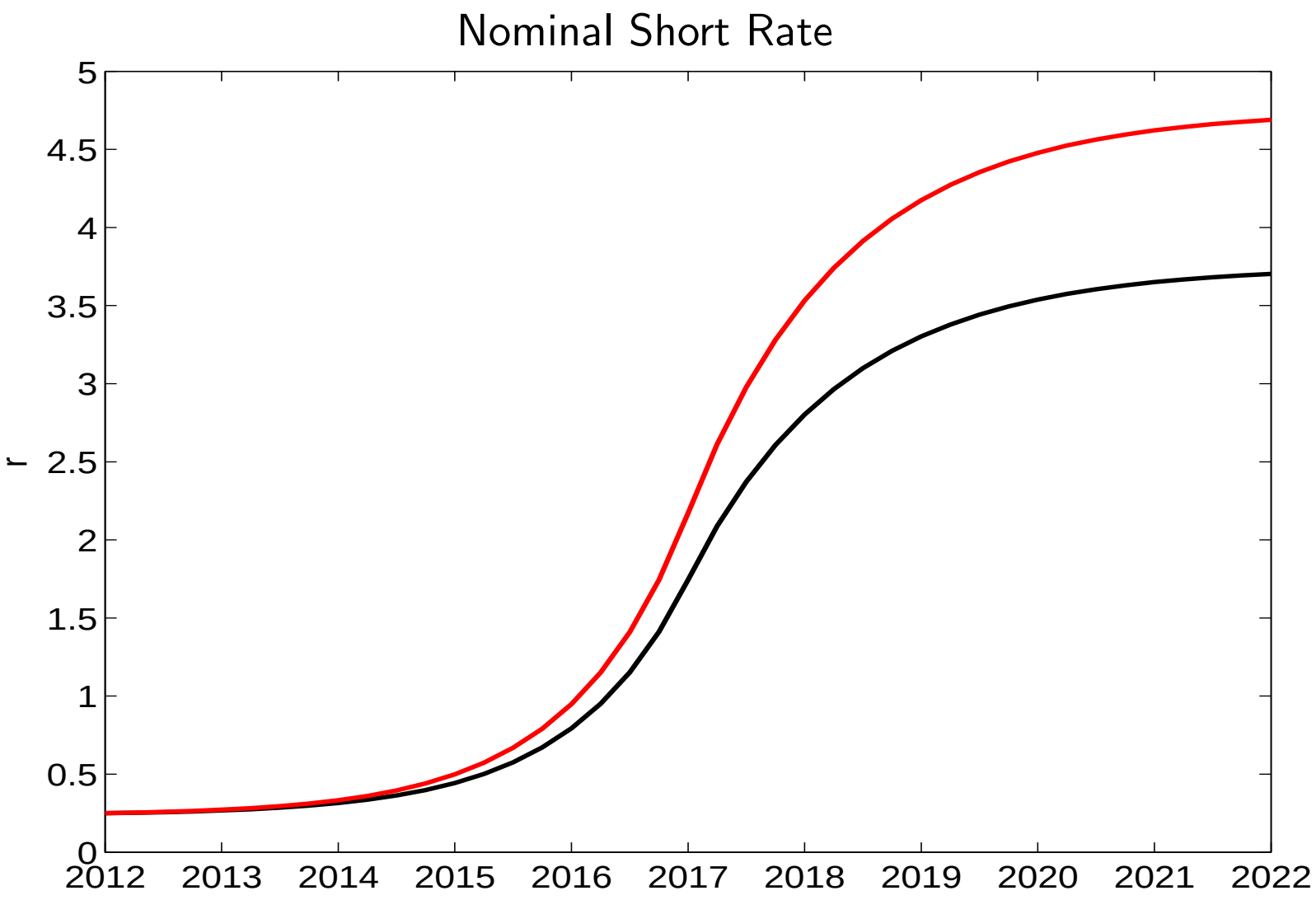
Baseline and scenarios

- Baseline: real rate path chosen so that r path roughly matches Carpenter et al.

- Scenarios (time 0 "surprise", perfect foresight afterwards)

  1. "Higher rates" Carpenter et al. scenario
  2. 10 year "inflation scare"
  3. Explosive paths (hyperinflations)

Baseline and "Higher Rates" Scenario



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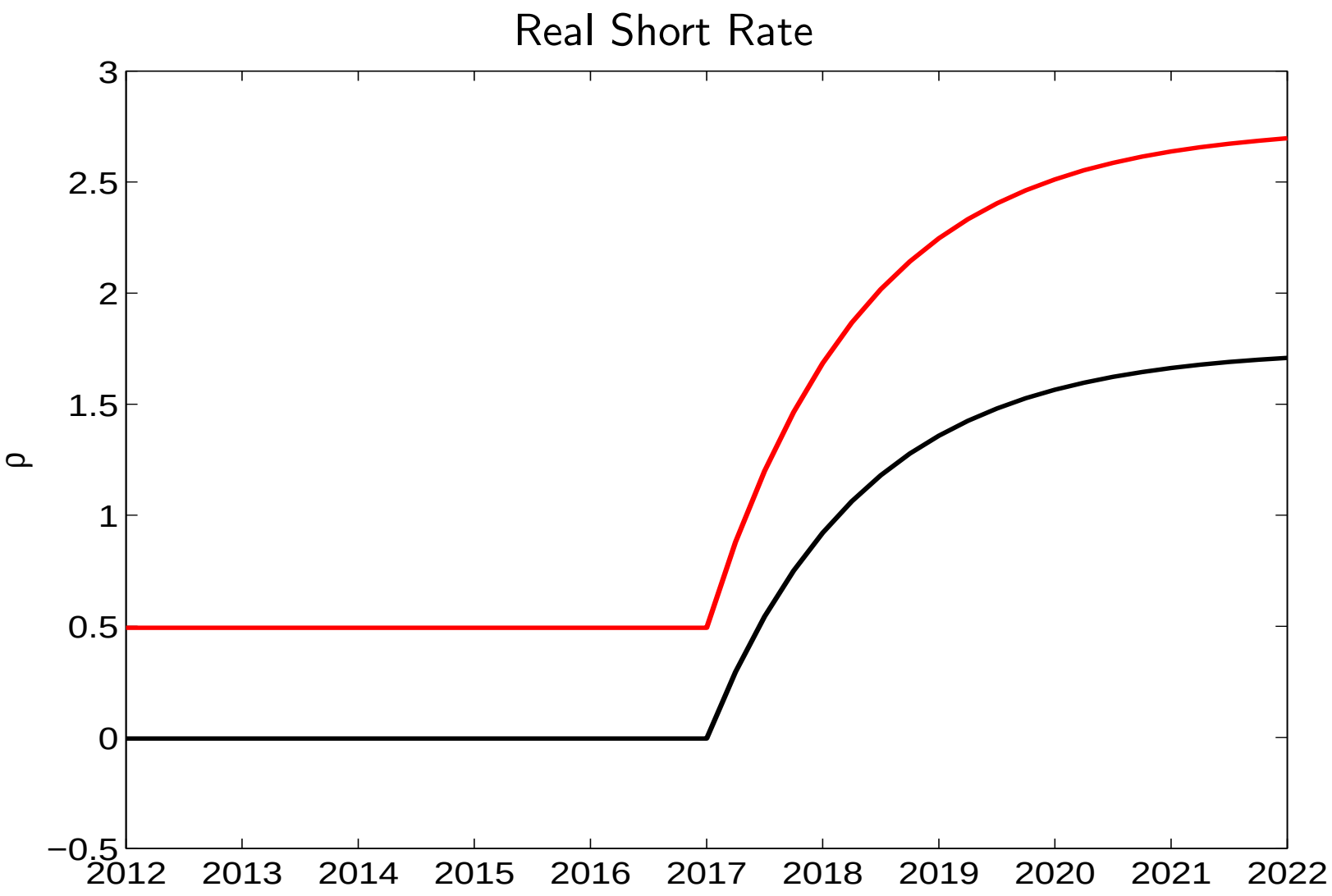
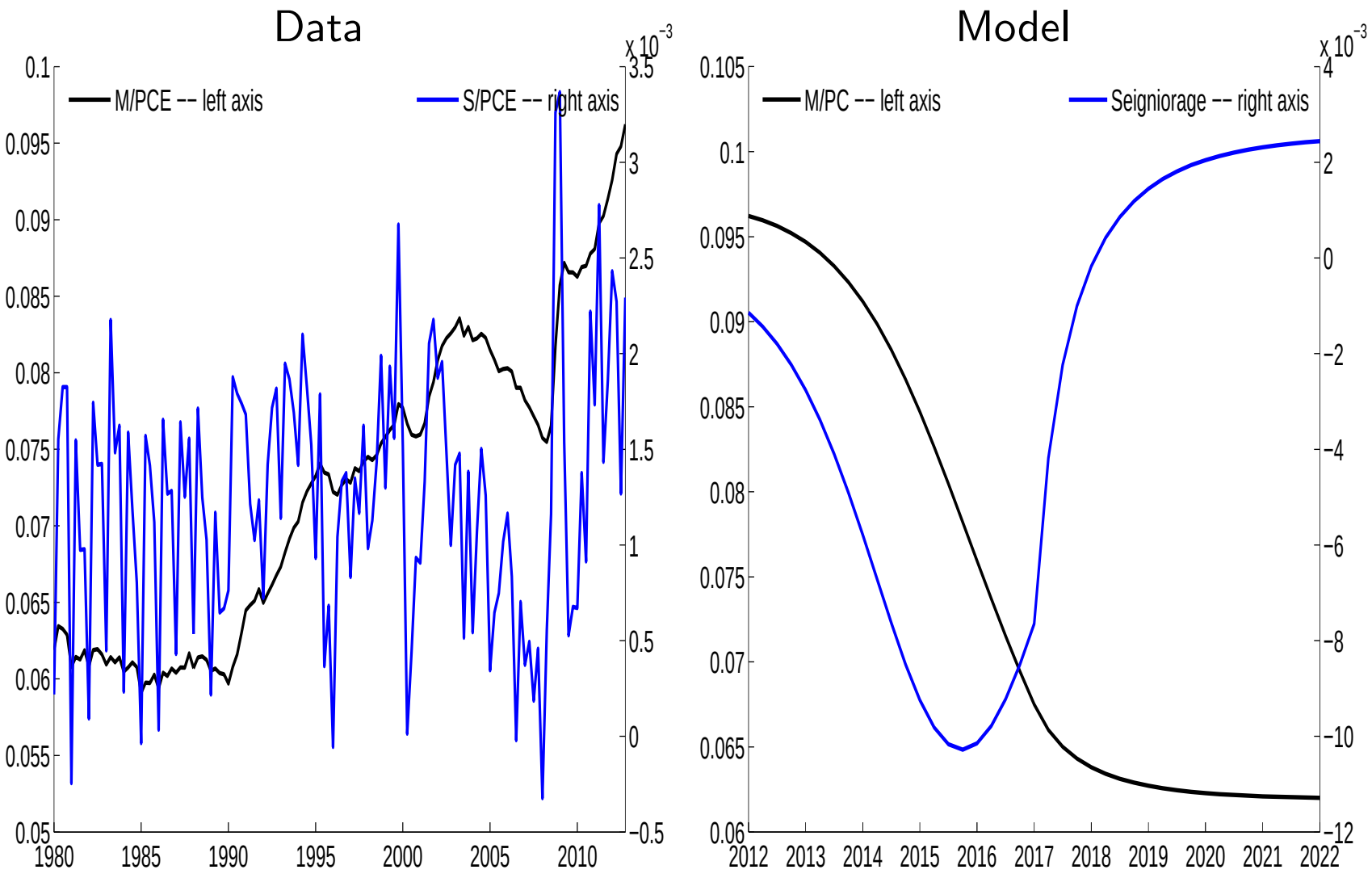


Balance Sheet Implications

	(1) qB/P $-V/P$	(2) PDV seig.	(3) (1)+(2)	(4) $\bar{\tau}^C$	(5) q	(6) $\Delta M/P$	(7) $\bar{B}/B$
(1) Baseline scenario	0.132	0.949	1.081	0.0024	1.11		
(2) Higher rates (β)	0.120	0.136	0.256	0.0028	1.09	-0.007	14.02
(3) Higher rates (γ)	0.132	1.238	1.369	0.0030	1.09	0.004	70.71

Seignorage and M/PC

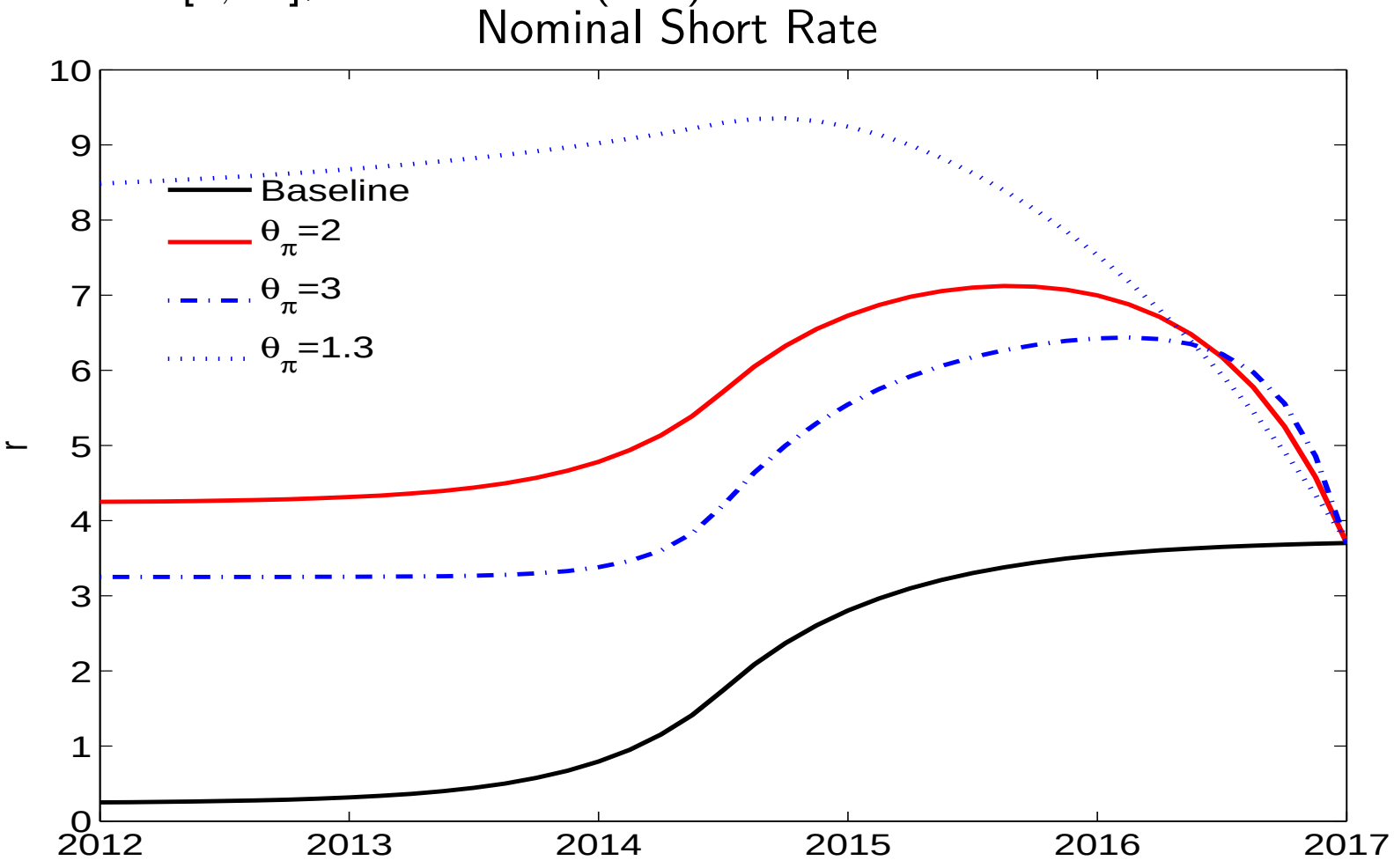


Inflation Scare – different θ_π's

- Fisher equation:

$$r_t = \rho_t + \frac{\dot{P}_t}{P_t} + x$$

for $t \in [0, 10]$, where $x = P(\Delta P) \times \Delta P$



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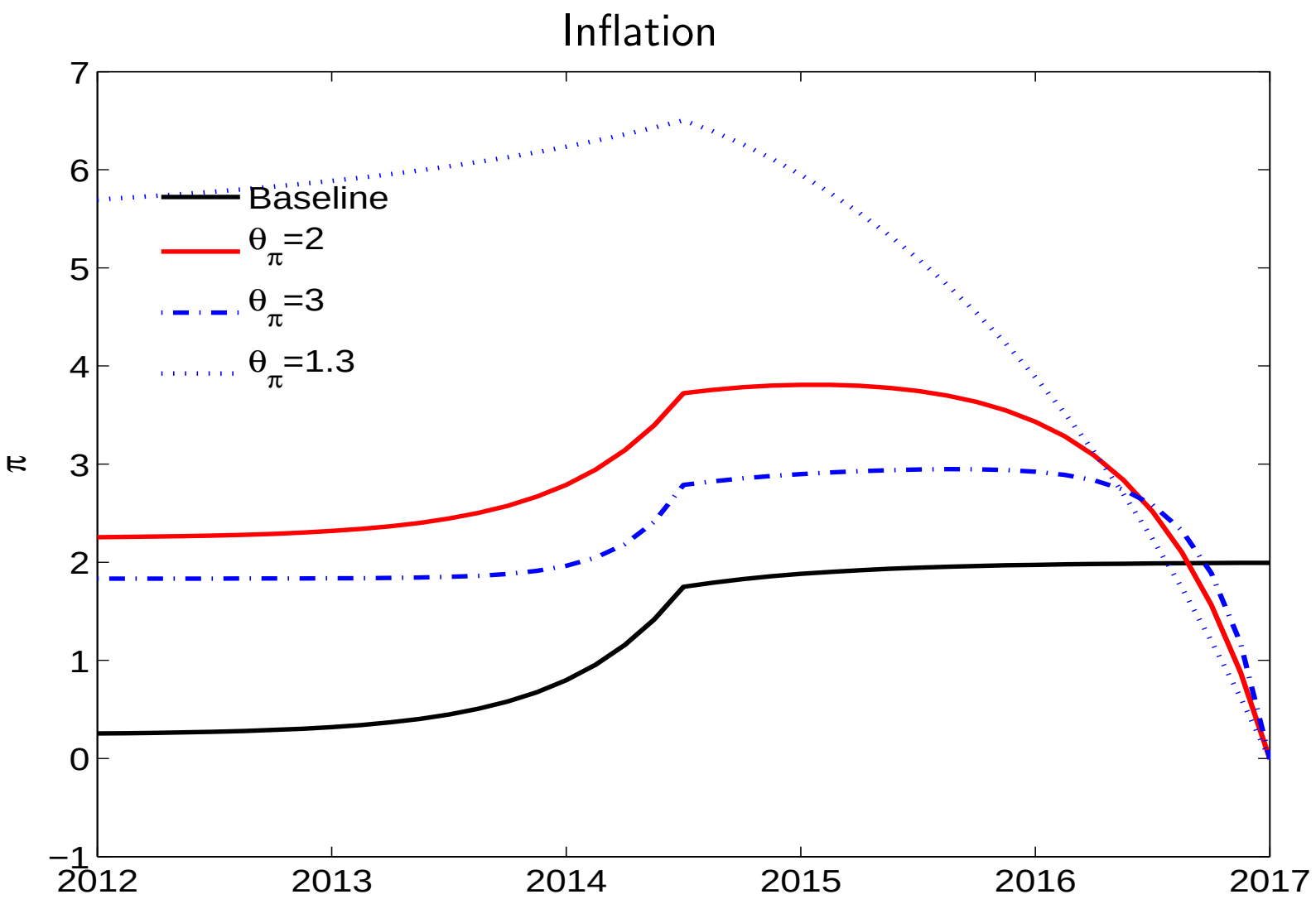
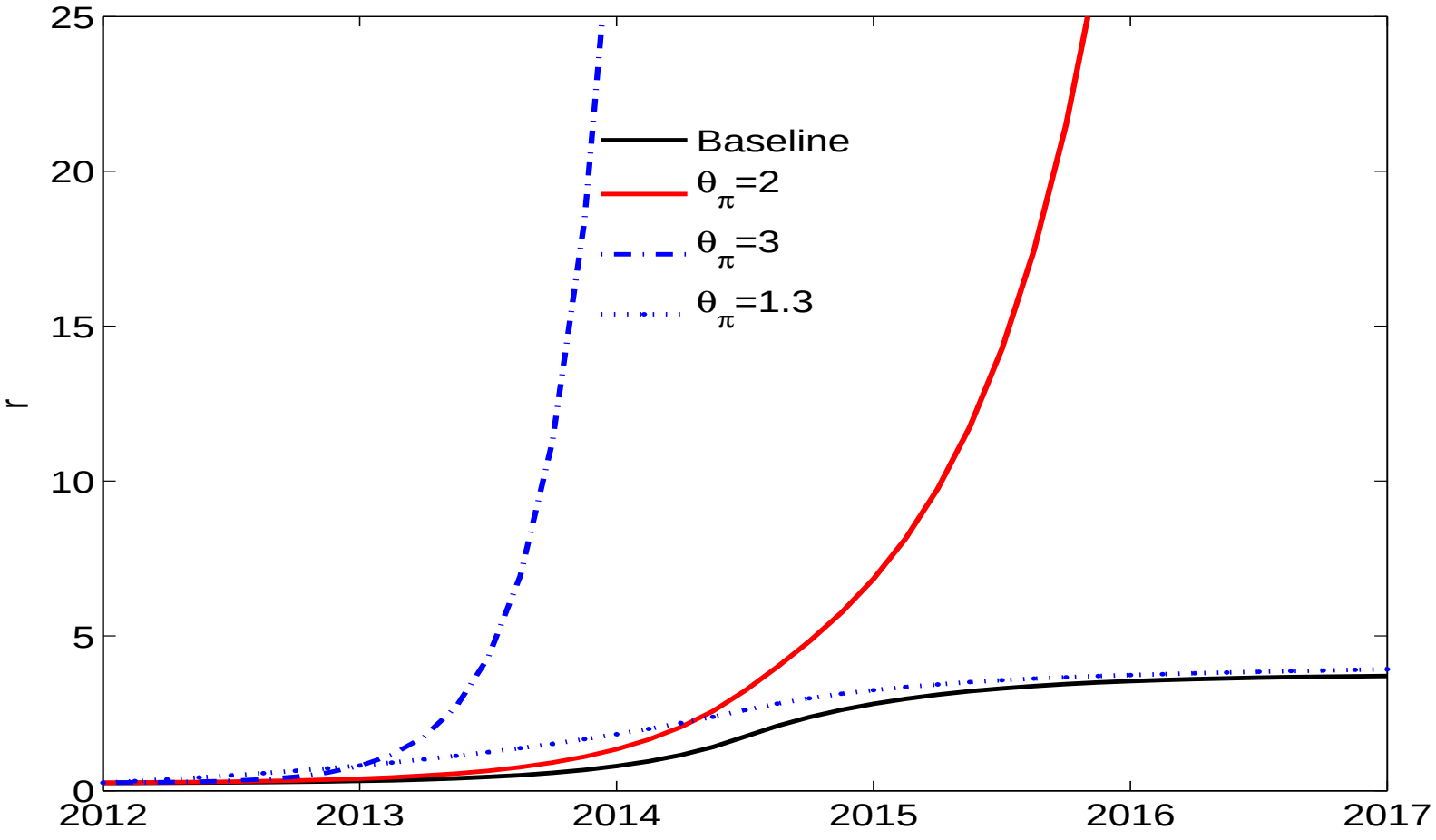


Balance Sheet Implications / Inflation Scare

	(1) qB/P $-V/P$	(2) PDV seig.	(3) (1)+(2)	(4) $\bar{\tau}^C$	(5) q	(6) $\Delta M/P$	(7) $\bar{B}/B$
(1)Baseline scenario	0.132	0.949	1.081	0.0024	1.11		
(4) Inflation scare	0.041	0.951	0.993	0.0022	0.94	-0.049	7.05
Higher θ_π							
(6) Inflation scare	0.053	0.905	0.958	0.0021	0.98	-0.048	8.25
Lower θ_π							
(8) Inflation scare	0.012	0.966	0.977	0.0023	0.81	-0.047	4.85

Explosive paths – different θ_π's

- Explosive paths: $r_t = \text{stable solution} + \kappa e^{\theta_r(\theta_\pi - 1)t}$



Balance Sheet Implications /Explosive path

	(1) qB/P $-V/P$	(2) PDV seig.	(3) (1)+(2)	(4) $\bar{\tau}^C$	(5) q	(6) $\Delta M/P$	(7) $\bar{B}/B$
(1)Baseline scenario	0.132	0.949	1.081	0.0024	1.11		
(5) Explosive path	3.924	Inf	Inf	Inf	0.89	3.843	Inf
Higher θ_π							
(7) Explosive path	8.060	Inf	Inf	Inf	0.65	8.036	Inf
Lower θ_π							
(9) Explosive path	1.175	Inf	Inf	Inf	1.07	1.051	Inf

Balance Sheet Implications /Alternative Money Demand

	(1) qB/P $-V/P$	(2) PDV seig.	(3) (1)+(2)	(4) $\bar{\tau}^C$	(5) q	(6) $\Delta M/P$	(7) $\bar{B}/B$
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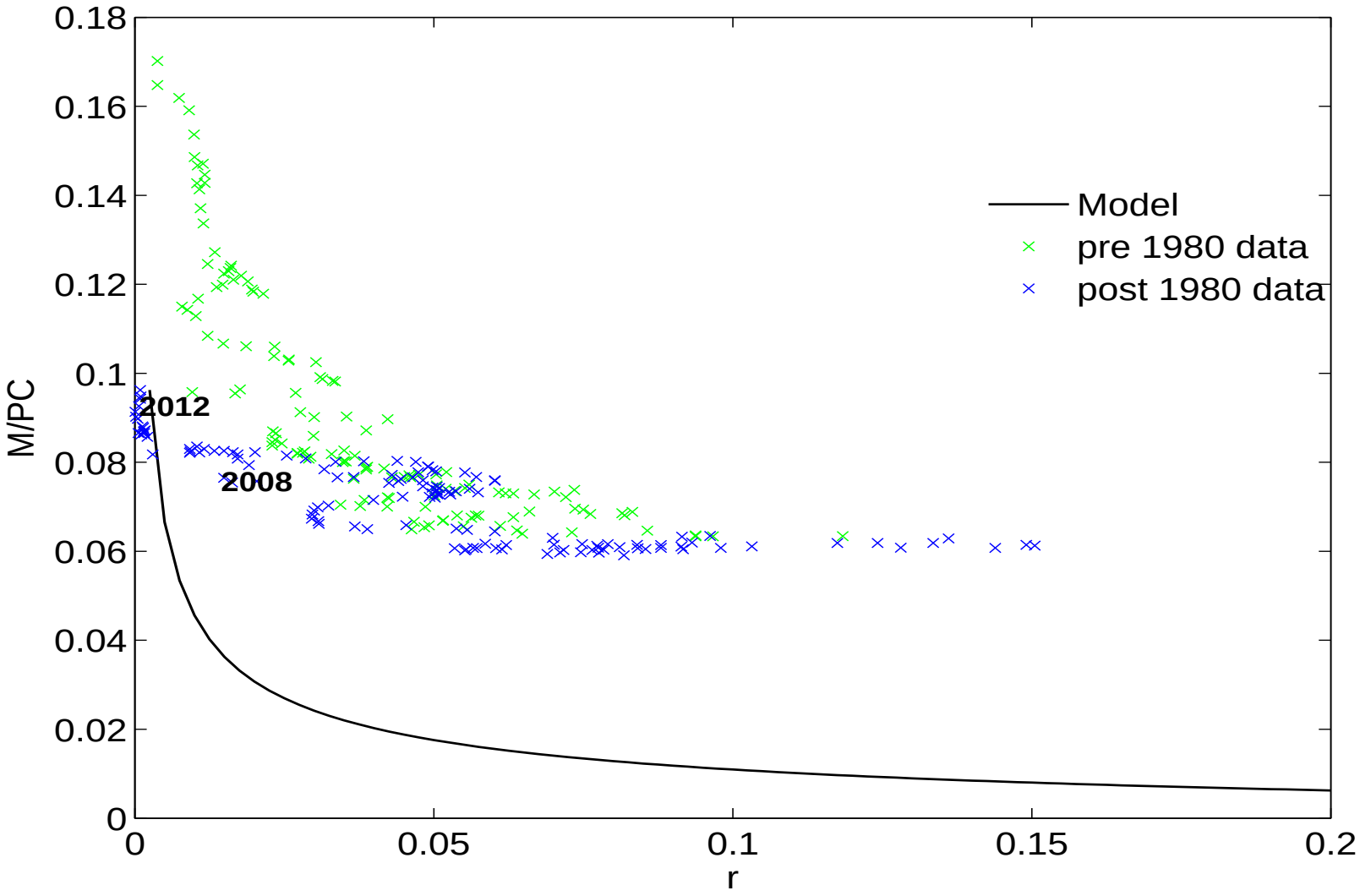
(4) Inflation scare	0.041	0.951	0.993	0.0022	0.94	-0.049	7.05
(5) Explosive path	3.924	Inf	Inf	Inf	0.89	3.843	Inf
Money demand $= 0$ for $r > 100\%$							
(10) Baseline scenario	0.132	0.263	0.396	0.0009	1.11		
(11) Inflation scare	-0.011	0.253	0.242	0.0005	0.94	-0.102	2.47
(12) Explosive path	0.079	-0.120	-0.041	-0.0001	0.89	-0.003	0.80

A scatter plot of short term interest rates and M/PC /Alternative Money Demand



Conclusions

Four levels of CB balance sheet problems: How likely?

1. Level 1: Accounting capital (book value of $B^C - V - M) < 0$. Or rule for remittances implies $\tau^C = 0$ for some period.
   - Likely (as in Carpenter et al.), but do not require fiscal support. In fact, PDV of remittances may actually increase.

2. Level 2: $qB^C - V < 0$
   - Possible, but not likely. In any case, no fiscal support required as long as PDV seignorage $\int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt > V - qB^C$.
   - The likelihood likely depends on conventional monetary policy (θ_π).

1. Level 3: $qB^C - V + \int_0^\infty \frac{\dot{M}_t}{P_t} e^{-\int_0^t \rho_s ds} dt < 0$
   - Unlikely – but very dependent on currency demand at high interest rates (which we do not know much about).

2. Level 4: Explosive paths/hyperinflation
   - May not be ruled out without fiscal support / switch to active fiscal policy.